642.01 General

To maintain the desired design speed, highway and ramp curves are usually superelevated to overcome part of the centrifugal force that acts on a vehicle.

See the following chapters for additional information:

Chapter	Subject
430	roadway widths and cross slopes for modified design level
440	minimum lane and shoulder widths for full design level
940	lane and shoulder widths for ramps

642.02 References

Standard Plans for Road, Bridge, and Municipal Construction (Standard Plans), M 21-01, WSDOT

Plans Preparation Manual, M 22-31, WSDOT

Standard Specifications for Road, Bridge, and Municipal Construction (Standard Specifications), M 41-10,WSDOT.

A Policy on Geometric Design of Highways and Streets (Green Book), 2001, AASHTO

642.03 Definitions

lane A strip of roadway used for a single line of vehicles.

lane width The lateral design width for a single lane, striped as shown in the Standard Plans and the Standard Specifications.

median The portion of a highway separating the traveled ways for traffic in opposite directions.

roadway The portion of a highway, including shoulders, for vehicular use.

superelevation The rotation of the roadway cross section in such a manner as to overcome part of the centrifugal force that acts on a vehicle traversing a curve.

superelevation runoff The length of highway needed to accomplish the change in cross slope from a section with adverse crown removed (level) to a fully superelevated section, or vice versa.

superelevation transition length The length of highway needed to change the cross slope from normal crown or normal pavement slope to full superelevation.

tangent runout The length of highway needed to change the cross slope from normal crown to a section with adverse crown removed (level).

traveled way The portion of the roadway intended for the movement of vehicles, exclusive of shoulders and lanes for parking, turning, and storage for turning.

turning roadway A curve on an open highway, a ramp, or the connecting portion of roadway between two intersecting legs of an intersection.

642.04 Rates for Open Highways and Ramps

The maximum superelevation rate allowed for open highways or ramps is 10%. (See Figure 642-3a.)

Base superelevation rate and its corresponding radius for open highways on Figure 642-3a, Superelevation Rate (10% Max), with the following exceptions:

- Figure 642-3b, Superelevation Rate (6% Max), may be used under the following conditions:

  1. Urban non freeways.

  2. Mountainous areas or locations that normally experience regular accumulations of snow and ice.

  3. Short-term detours (generally implemented and removed in one construction season). For long-term detours, consider a higher rate up to 10%, especially when associated with a main line detour.

- Figure 642-3c, Superelevation Rate (8% Max), may be used for existing roadways, urban freeways, and areas where the 6% rate is allowed but will not work; for example, where a curve with a radius less than the minimum for the 6 % rate at the design speed is required.

Design the superelevation for ramps the same as for open highways. With justification, superelevation for ramps in urban areas with a design speed of 40 mph or less, may be determined as an urban managed access highway [642.05 & Figure 642-4].

Round the selected superelevation rate to the nearest full percent.

Document which set of curves is being used and, when a curve other than the 10% maximum rate is used, document why the curve was selected.

Depending on design speed, construct large radius curves with a normal crown section. The minimum radii for normal crown sections are shown in Figure 642-1. Superelevate curves with smaller radii in accordance with the appropriate superelevation from Figures 642-3a through 3c.

Design Speed (mph)	Minimum Radius for Normal Crown Section (ft)
15	955
20	1695
25	2,450
30	3,340
35	4,375
40	5,545
45	6,860
50	8,315
55	9,920
60	11,675
65	13,130
70	14,675
75	16,325
80	18,065

Minimum Radius for Normal Crown Section

Figure 642-1

642.05 Rates for Low-Speed Urban Managed Access Highway

Curves on low-speed Urban Managed Access Highways may be superelevated using a higher side friction than used for open highways. Figure 642-4 may be used to determine superelevation for Urban Managed Access Highways with a design speed of 40 mph or less. Figure 642-4 was developed using the higher side friction.

642.06 Existing Curves

Evaluate the superelevation on an existing curve to determine its adequacy. Use the following equation to determine the minimum radius for a given superelevation and design speed:

$$R = \frac{6.69\,V^2}{e + f}$$

Where:

R = The minimum allowable radius of the curve in feet.

V = Design speed in mph

e = Superelevation rate in percent

f = Side friction factor from Figure 642-2

Superelevation is deficient when the existing radius is less than the minimum from the equation.

For preservation projects, where the existing pavement is to remain in place, the superelevation on existing curves may be evaluated with a ball banking analysis.

Corrective action is required to address deficient superelevation, when the existing radius is less than the minimum radius calculated using the equation or when the maximum speed determined by a ball banking analysis is less than the design speed. Provide superelevation as given in 642.04.

Design Speed (mph)	Side Friction Factor (*f*)
15	17.5
20	17
25	16.5
30	16
35	15.5
40	15
45	14.5
50	14
55	13
60	12
65	11
70	10
75	9
80	8

Side Friction Factor

Figure 642-2

642.07 Turning Movements at Intersections

Curves associated with the turning movements at intersections are superelevated using the side friction factors for low-speed urban managed access highway curves. Since speeds of turning vehicles are not constant and curve lengths are not excessive, these higher friction factors can be tolerated. Use superelevation rates as high as practical, consistent with curve length and climatic conditions. Figure 642-4 shows the minimum superelevation for given design speed and radius. Use judgment in considering local conditions such as snow and ice. When using high superelevation rates on short curves, provide smooth transitions with merging ramps or roadways.

642.08 Runoff for Highway Curves

For added comfort and safety, provide uniform superelevation runoff over a length adequate for the likely operating speeds. The length of the runoff is based on a maximum allowable difference between the grades on the pivot point and the outer edge of the traveled way for one 12 ft lane.

Provide transitions for all superelevated highway curves as specified in Figures 642-5a through 5e. Which transition to use depends on the location of the pivot point, the direction of the curve, and the roadway cross slope.

Consider the profile of the edge of traveled way. To be pleasing in appearance, do not let it appear distorted. The combination of superelevation transition and grade may result in a hump or dip in the profile of the edge of traveled way. When this happens, the transition may be lengthened to eliminate the hump or dip. If the hump or dip cannot be eliminated this way, pay special attention to drainage in the low areas.

When reverse curves are necessary, provide sufficient tangent length for complete superelevation runoff for both curves (that is, from full superelevation of the first curve to level to full superelevation of the second curve). If tangent length is longer than this but not sufficient to provide full super transitions (that is, from full superelevation of the first curve to normal crown to full superelevation of the second curve), increase the superelevation runoff lengths until they abut. This provides one continuous transition, without a normal crown section, similar to Designs C2 and D2 in Figures 642-5c and 5d except full super will be attained rather than the normal pavement slope as shown.

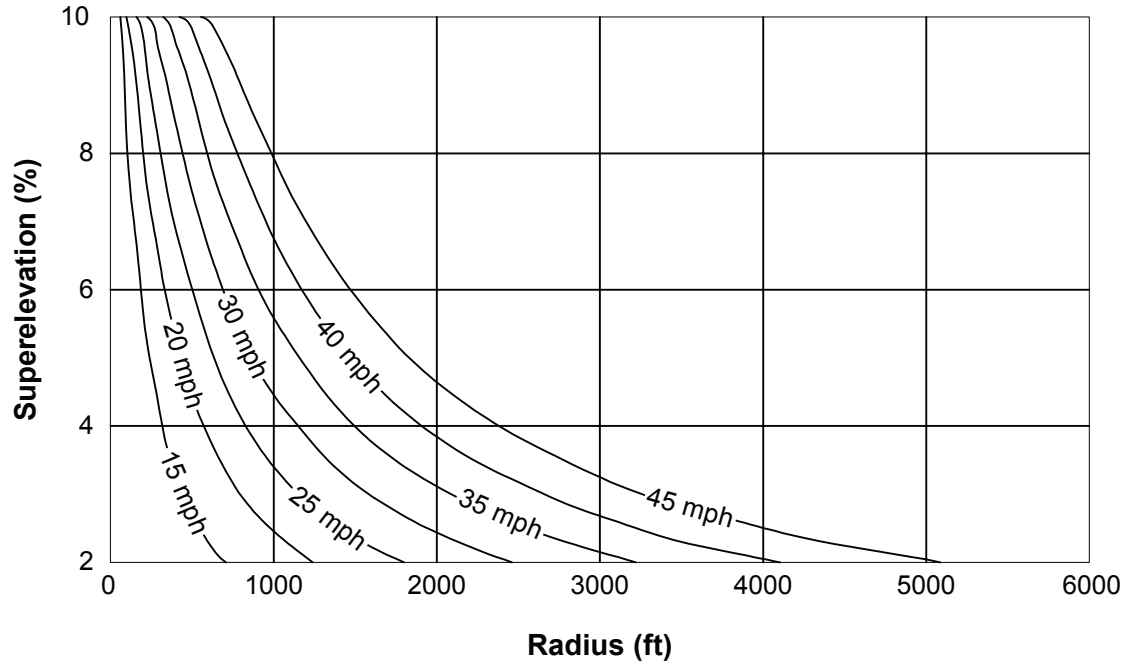
Superelevation runoff is permissible on structures but not desirable. Whenever practical, strive for full super or normal crown slopes on structures.

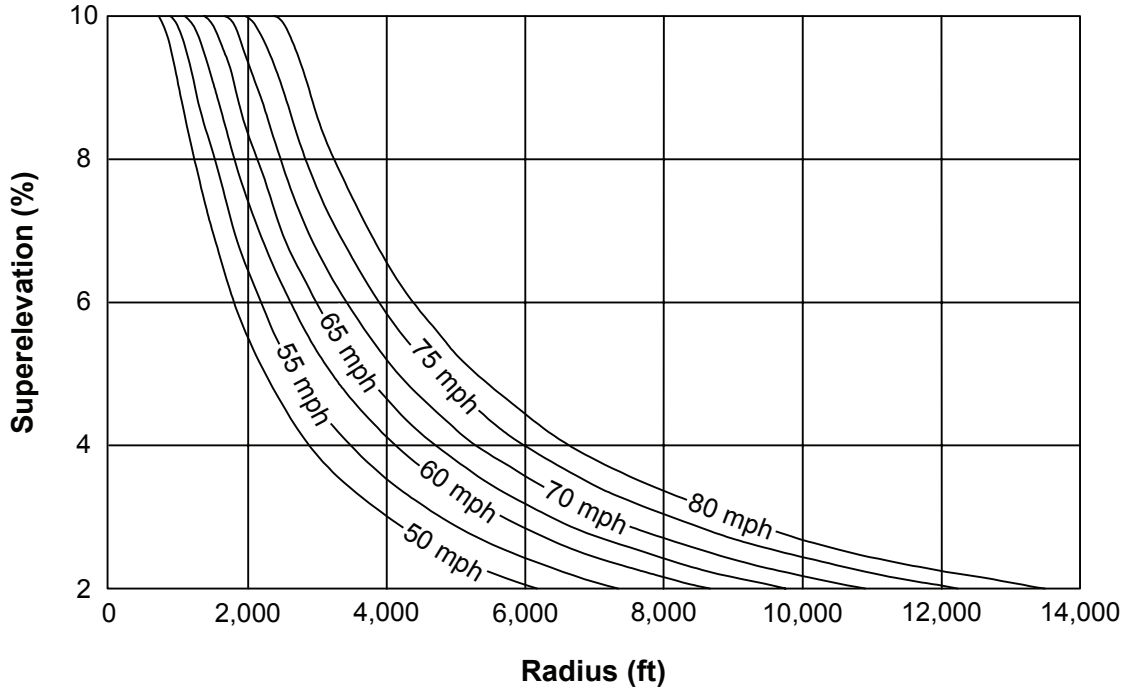
642.09 Runoff for Ramp Curves

Superelevation runoff for ramps use the same maximum relative slopes for specific design speeds used for highway curves. Multilane ramps have a width similar to the width for highway lanes; therefore, Figures 642-5a through 5e are used to determine the superelevation runoff for ramps. Single lane ramps have a lane width of 15 ft in curves, requiring the runoff length to be adjusted. Superelevation transition lengths (L_T) for single-lane ramps are given in Figures 642-6a and 6b. Additional runoff length for turning roadway widening is not required.

642.10 Documentation

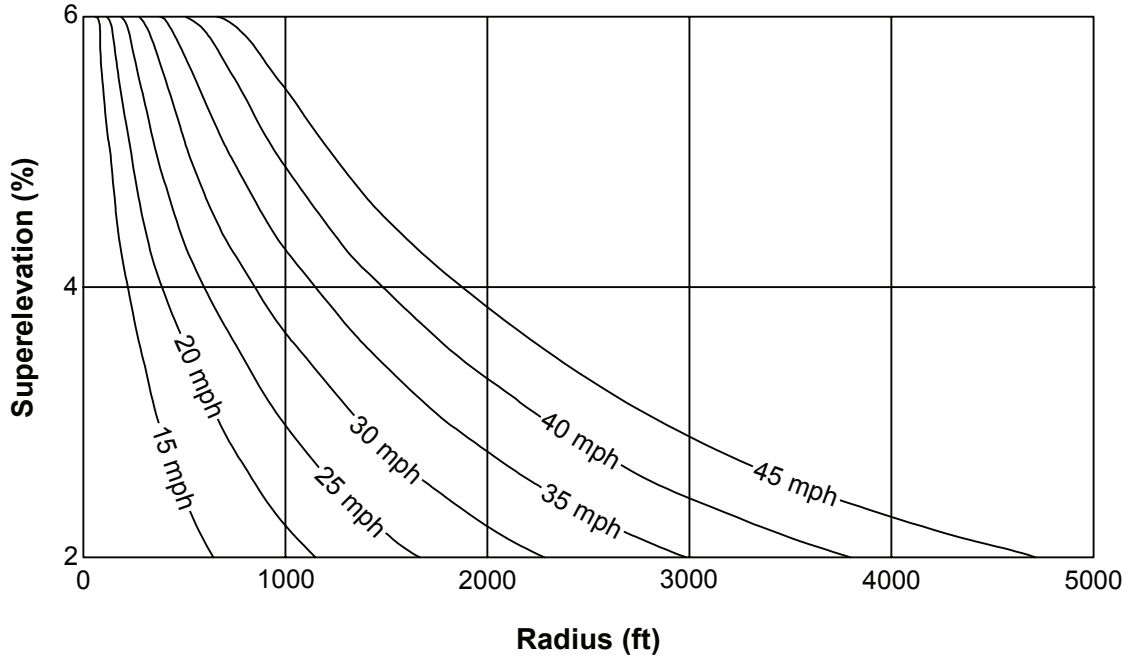
A list of the documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following web site: http://www.wsdot.wa.gov/eesc/design/projectdev/

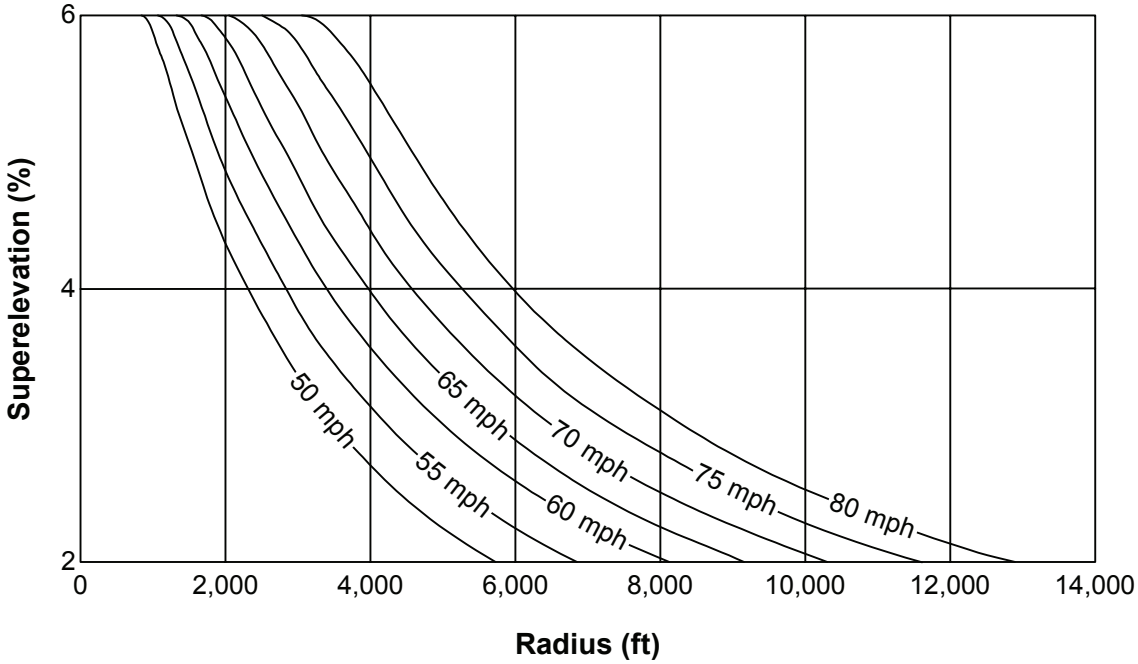




Design Speed (mph)	15	20	25	30	35	40	45	50	55	60	65	70	75	80
Minimum Radius (ft)	55	100	160	235	325	430	555	700	880	1095	1345	1640	1980	2380

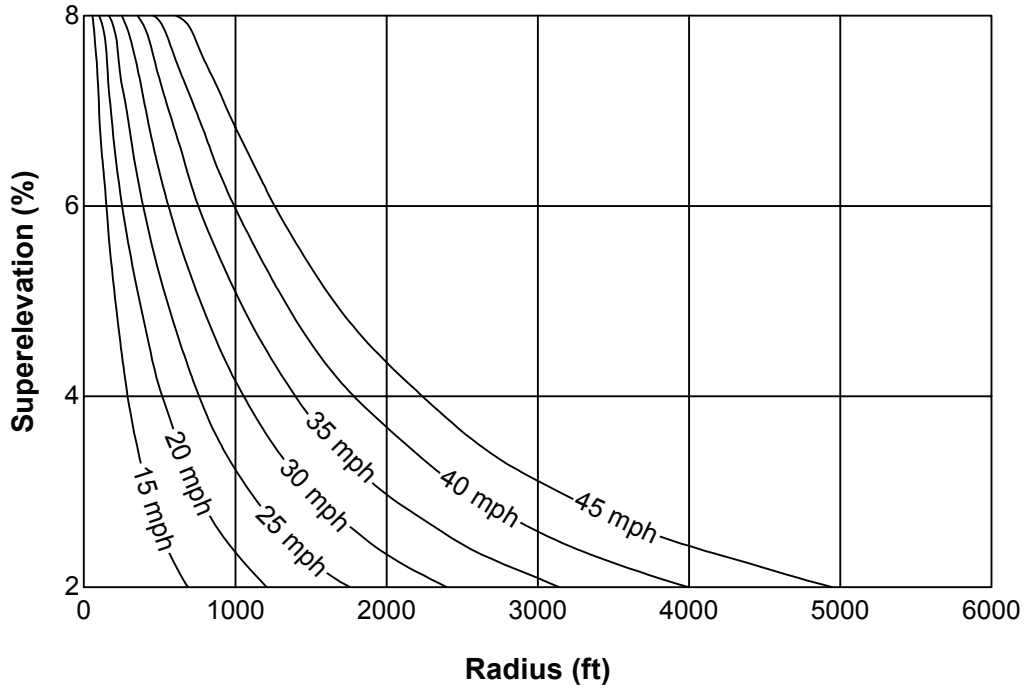
Superelevation Rates (10% max)
Figure 642-3a

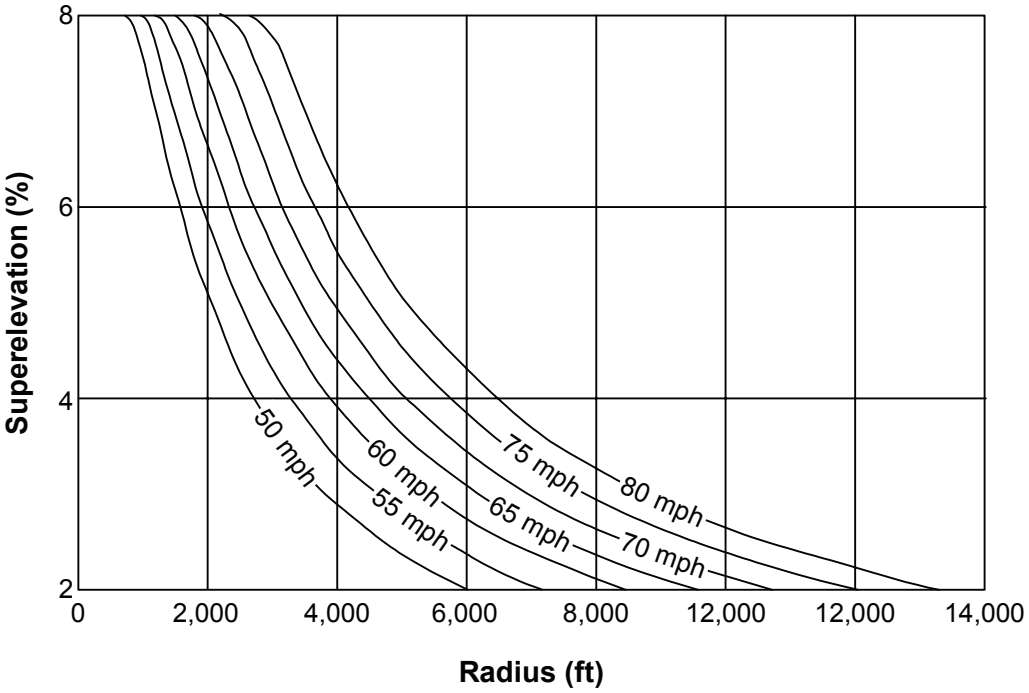




Design Speed (mph)	15	20	25	30	35	40	45	50	55	60	65	70	75	80
Minimum Radius (ft)	65	120	190	270	385	510	660	840	1065	1340	1665	2050	2510	3055

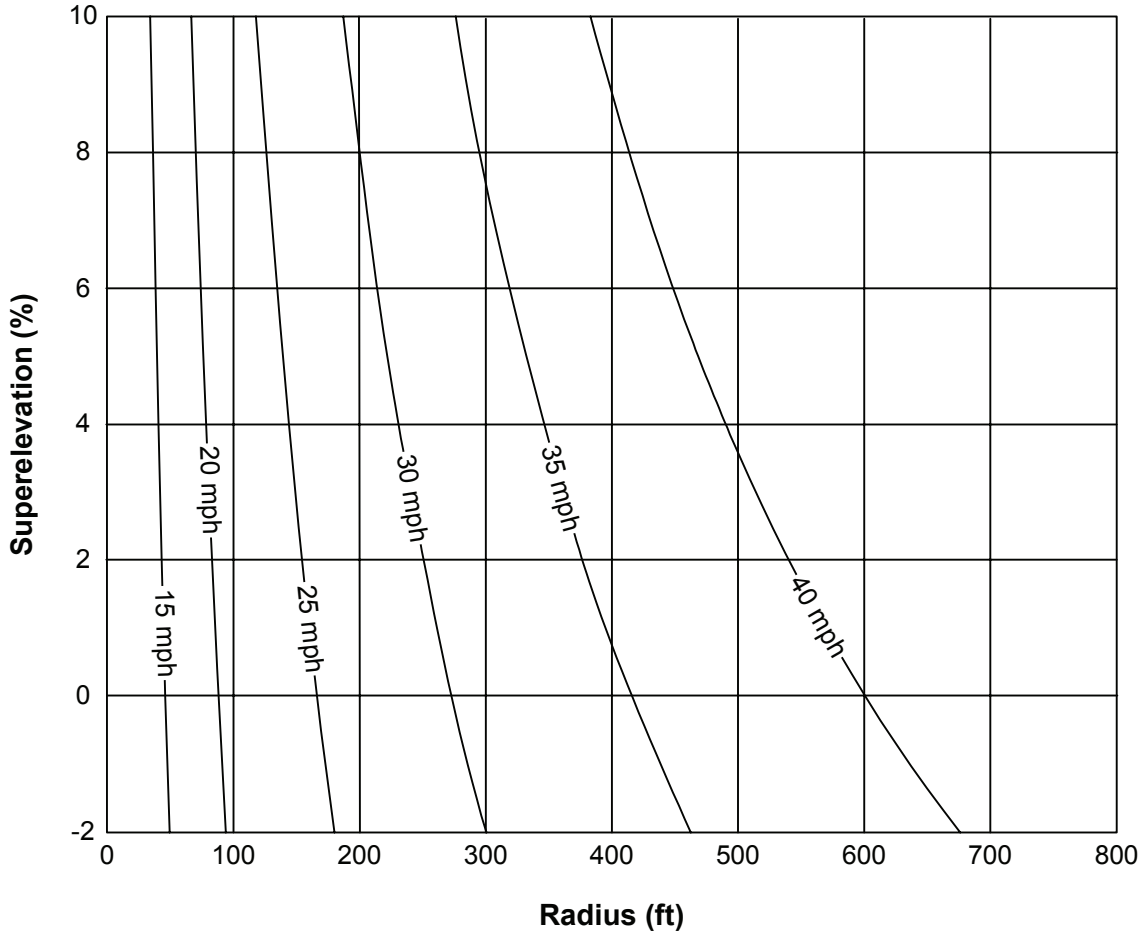
Superelevation Rates (6% max)
Figure 642-3b





Design Speed (mph)	15	20	25	30	35	40	45	50	55	60	65	70	75	80
Minimum Radius (ft)	60	110	175	255	350	465	605	760	965	1205	1490	1820	2215	2675

Superelevation Rates (8% max)
Figure 642-3c



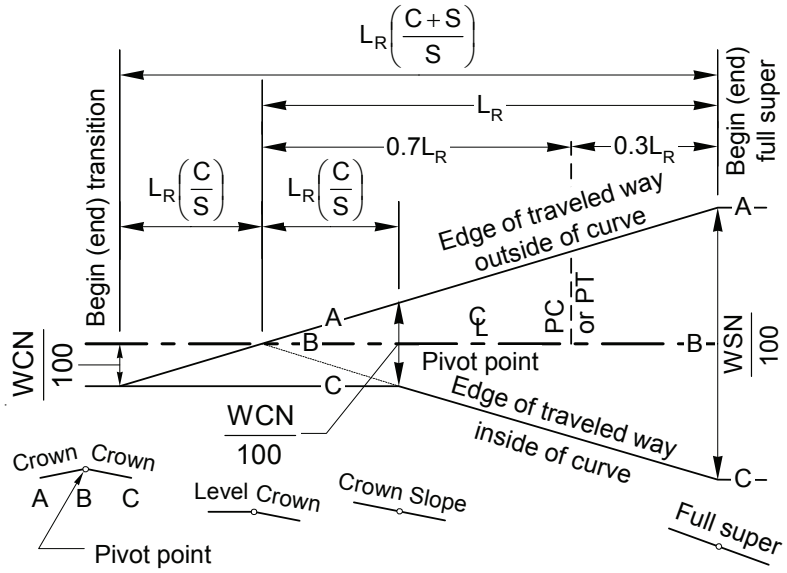
Superelevation Rates for Low-Speed Urban Managed Access Highways
Figure 642-4

S (%)	L_B=Basic runoff in feet for Design Speed of:													
	15 mph	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph	60 mph	65 mph	70 mph	75 mph	80 mph
2	30	30	35	35	40	40	45	50	50	55	55	60	65	70
3	45	50	50	55	60	60	65	70	75	80	85	90	95	105
4	60	65	70	75	75	85	90	95	100	105	110	120	125	135
5	75	80	85	90	95	105	110	120	130	135	140	150	160	170
6	90	95	105	110	115	125	135	145	155	160	170	180	190	205
7	110	115	120	130	135	145	155	170	180	185	195	210	220	240
8	125	130	135	145	155	165	180	190	205	215	225	240	250	275
9	140	145	155	165	175	185	200	215	230	240	250	270	285	310
10	155	160	170	180	195	205	220	240	255	265	280	300	315	345

* Based on one 12 ft lane between the pivot point and the edge of traveled way. When the distance exceeds 12 ft use the following equation to obtain L_R:
$L_R=L_B(1+0.04167X)$

Where:

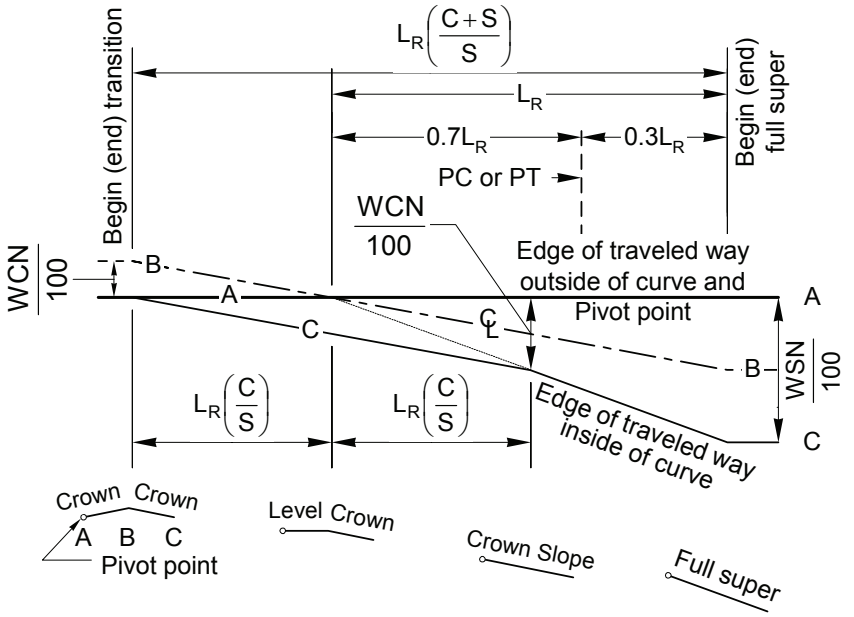
X = The distance in excess of 12 ft between the pivot point and the furthest edge of traveled way, in feet



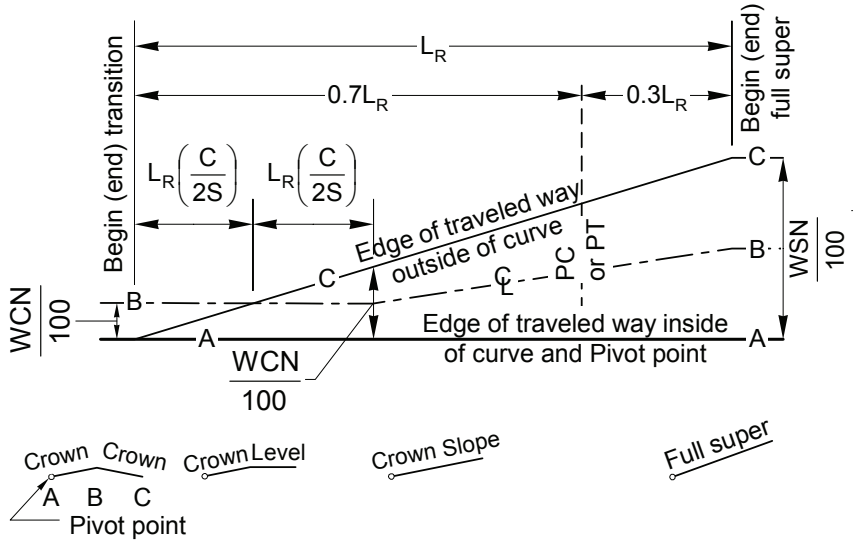
Design A Pivot Point on Center Line
Crown Section

C = Normal crown(%)
S = Superelevation rate (%)
N = Number of lanes between points
W = Width of lane

Superelevation Transitions for Highway Curves
Figure 642-5a



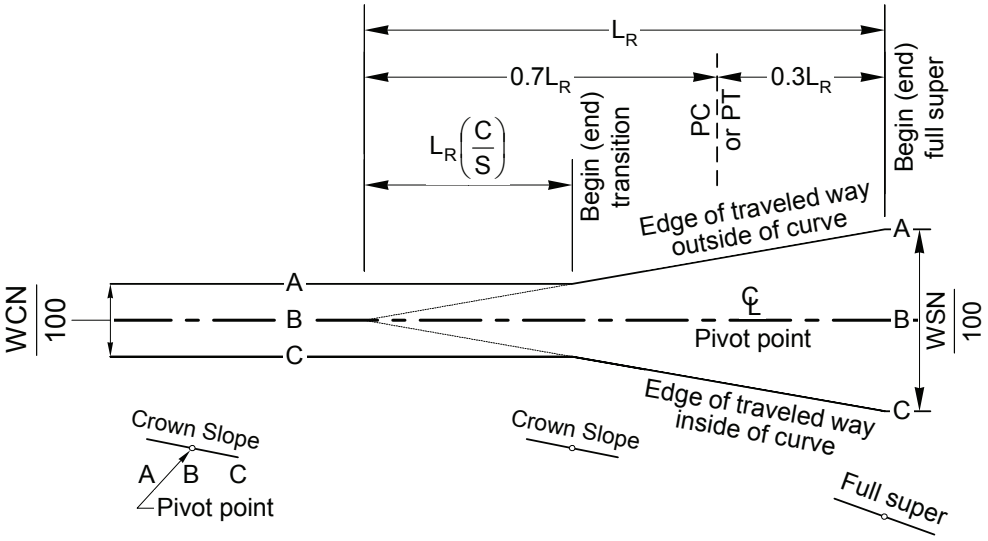
Design B[1] Pivot Point on Edge of Traveled Way
Outside of Curve Crowned Section



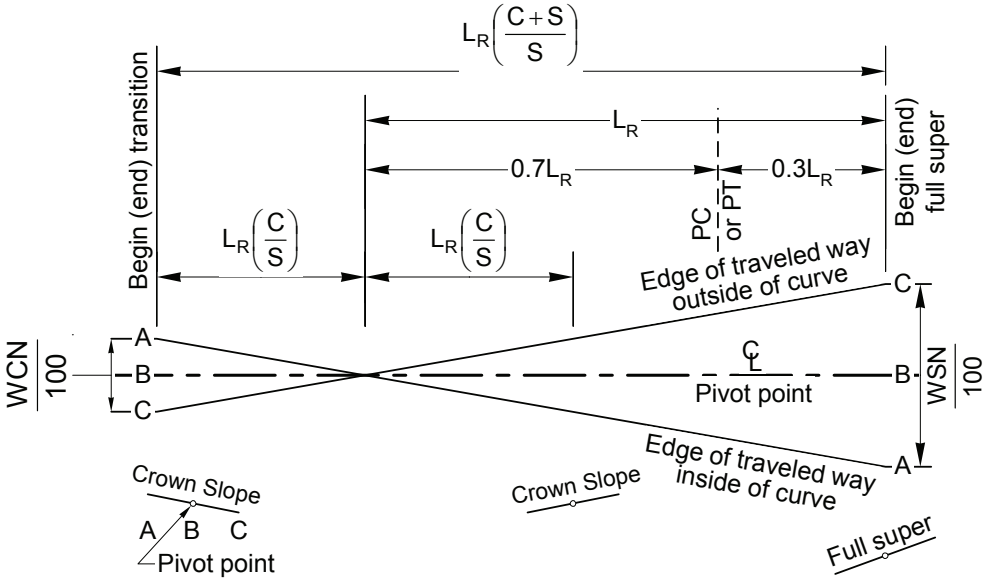
Design B[2] Pivot Point on Edge of Traveled Way
Inside of Curve Crowned Section

C = Normal crown(%)
S = Superelevation rate (%)
N = Number of lanes between points
W = Width of lane

Superelevation Transitions for Highway Curves
Figure 642-5b



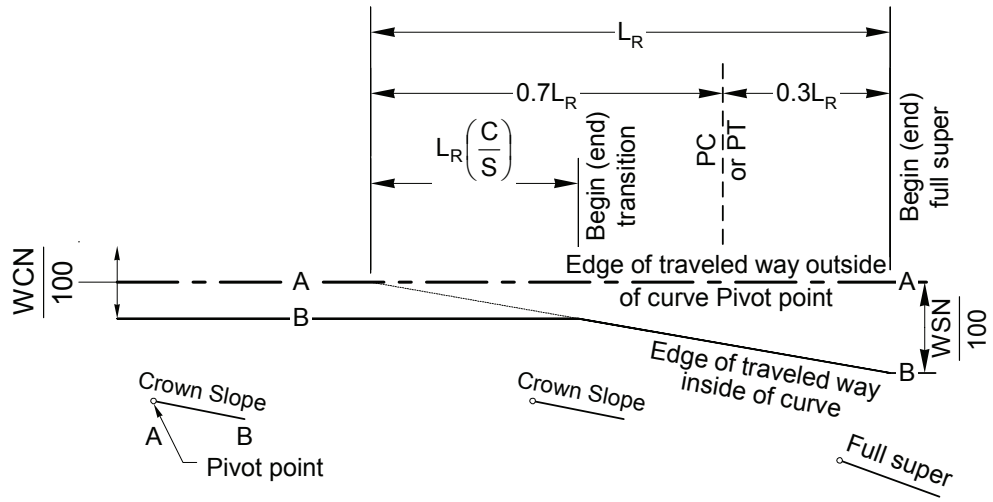
Design C[1] Pivot point on center line curve in direction of normal pavement slope - plane section



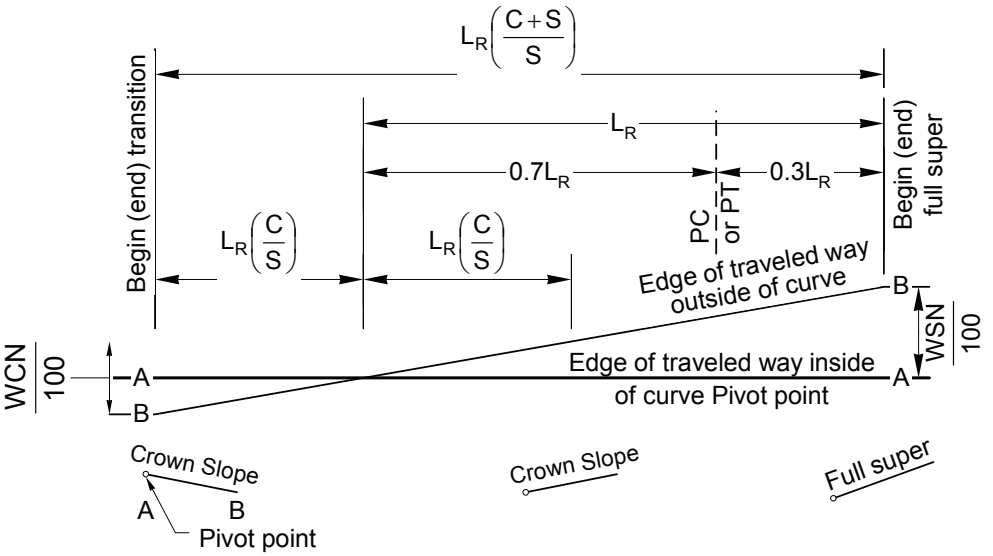
Design C[2] Pivot point on center line curve opposite to normal pavement slope - plane section

C = Normal crown(%)
S = Superelevation rate (%)
N = Number of lanes between points
W = Width of lane

Superelevation Transitions for Highway Curves
Figure 642-5c



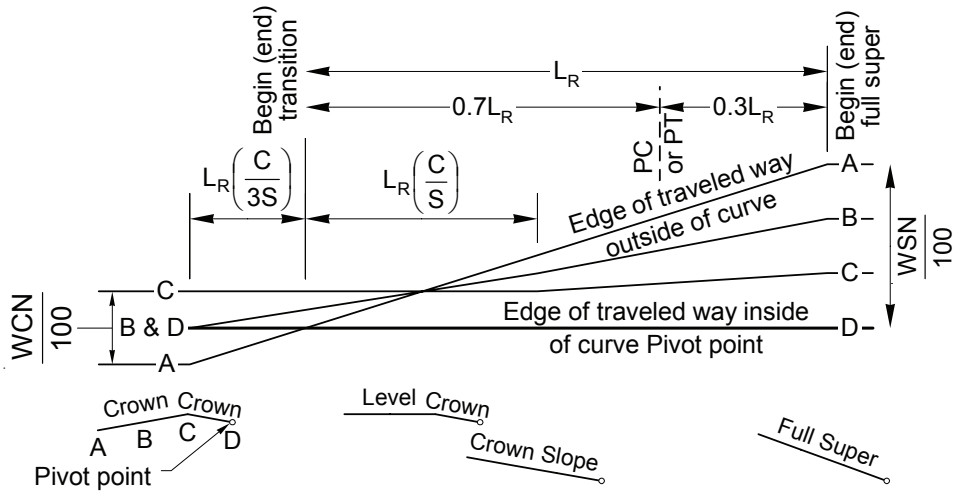
Design D[1] Pivot point on edge of traveled way curve in direction of normal pavement slope - plane section



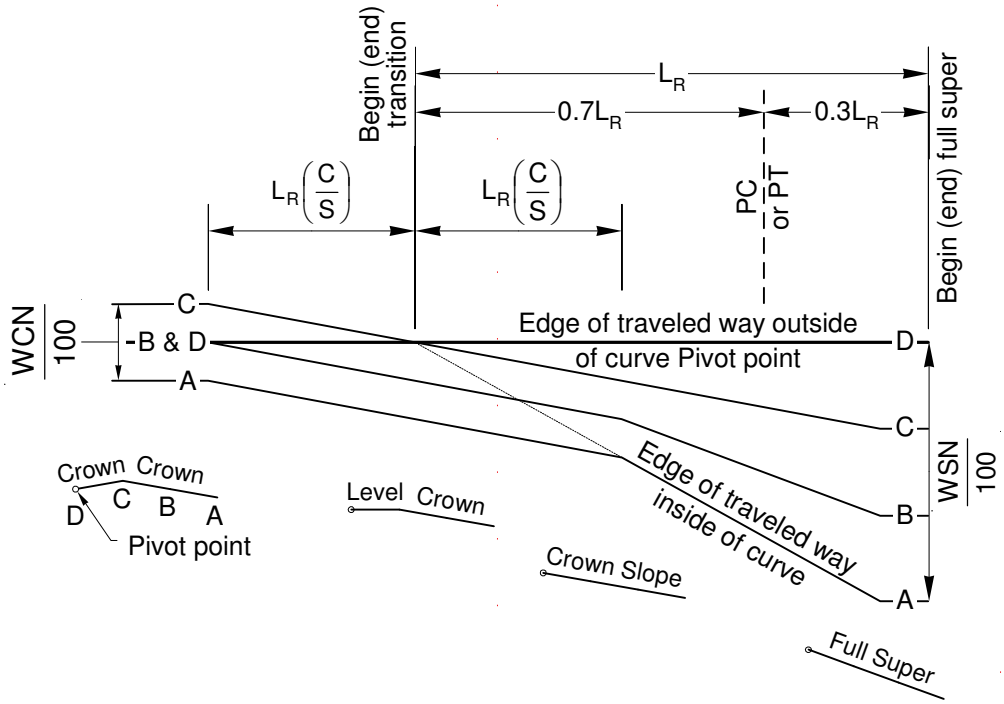
Design D[2] Pivot point on edge of traveled way curve opposite to normal pavement slope - plane section

C = Normal crown(%)
S = Superelevation rate (%)
N = Number of lanes between points
W = Width of lane

Superelevation Transitions for Highway Curves
Figure 642-5d



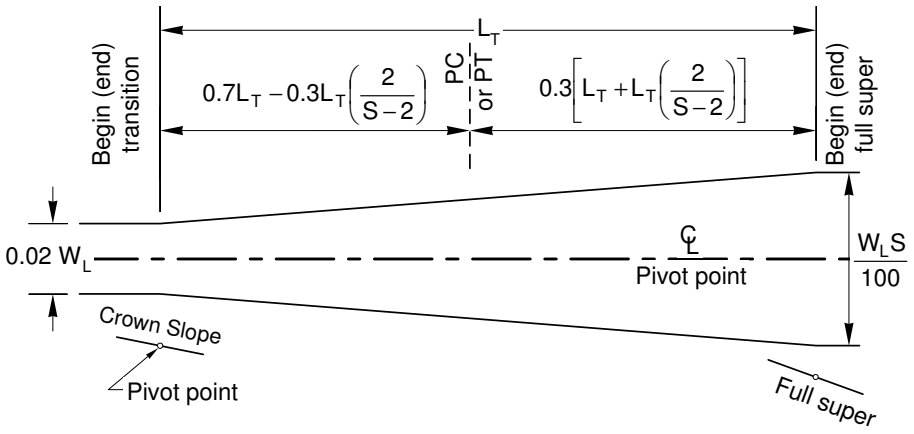
Design E[1] Six lane with median, pivot point on edge of traveled way inside of curve crown section



Design E[2] Six lane with median, pivot point on edge of traveled way outside of curve crown section

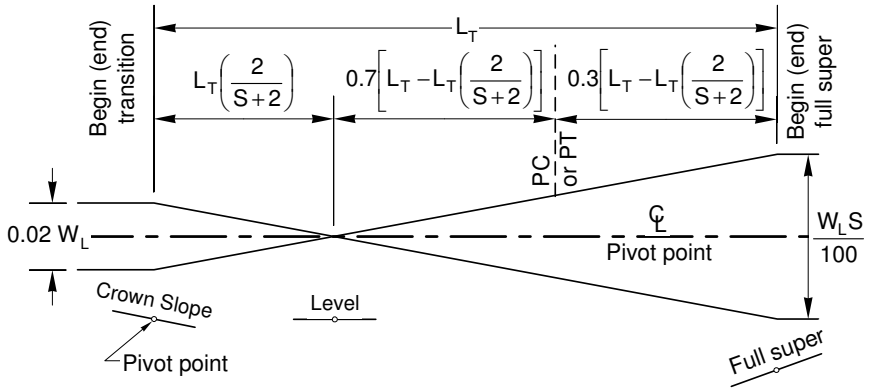
C = Normal crown(%)
S = Superelevation rate (%)
N = Number of lanes between points
W = Width of lane

Superelevation Transitions for Highway Curves
Figure 642-5e



S (%)	Length of transition in feet for Design Speed of:							
	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph
	L_T	L_T	L_T	L_T	L_T	L_T	L_T	L_T
3	10	15	15	15	15	15	15	15
4	20	25	25	25	25	30	30	35
5	30	35	35	35	40	45	45	50
6	40	45	45	50	55	55	60	65
7	50	55	55	60	65	70	75	80
8	60	65	70	75	80	85	90	95
9	70	75	80	85	95	100	105	110
10	80	85	90	100	105	115	120	130

Table 1 Pivot Point on Center Line — Curve in Direction of Normal Pavement Slope



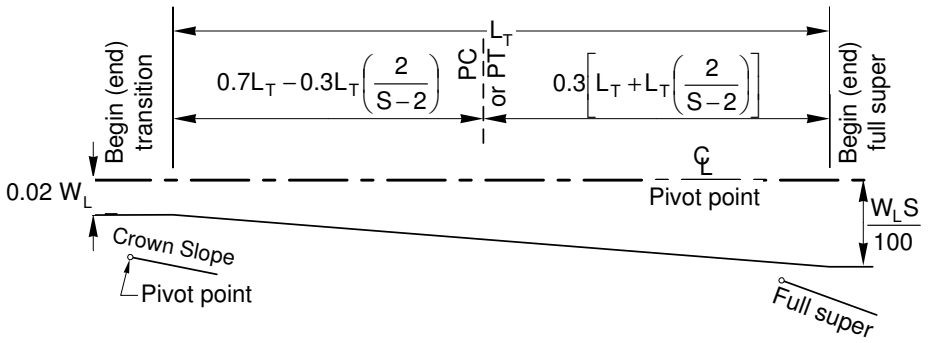
S (%)	Length of transition in feet for Design Speed of:							
	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph
	L_T	L_T	L_T	L_T	L_T	L_T	L_T	L_T
2	40	40	45	50	55	55	60	65
3	50	55	55	60	65	70	75	80
4	60	65	70	75	80	85	90	95
5	70	75	80	85	90	100	105	110
6	80	85	90	95	105	115	120	130
7	90	95	100	110	120	125	135	145
8	100	105	115	120	130	140	150	160
9	110	120	125	135	145	155	165	175
10	120	130	135	145	160	170	180	190

Table 2 Pivot Point on Center Line — Curve in Direction Opposite to Normal Pavement Slope

W_L=width of ramp lane.

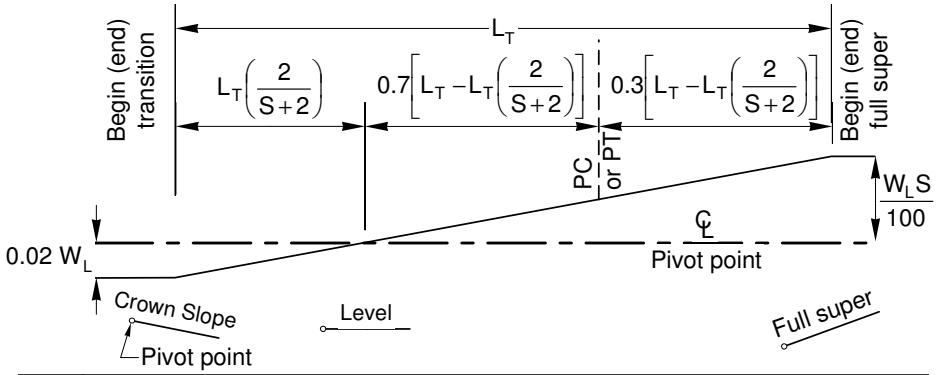
Superelevation Transitions for Ramp Curves

Figure 642-6a



S (%)	Length of transition in feet for Design Speed of:							
	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph
	L_T	L_T	L_T	L_T	L_T	L_T	L_T	L_T
3	20	25	25	25	25	30	30	35
4	40	45	45	50	55	55	60	65
5	60	65	70	75	80	85	90	95
6	80	85	90	100	105	115	120	130
7	100	105	115	120	130	140	150	160
8	120	130	135	145	160	170	180	190
9	140	150	160	170	185	195	210	225
10	160	170	180	195	210	225	240	255

Table 3 Pivot point on edge of traveled way — curve in direction of normal pavement slope



S (%)	Length of transition in feet for Design Speed of:							
	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph
	L_T	L_T	L_T	L_T	L_T	L_T	L_T	L_T
2	80	85	90	100	105	115	120	130
3	100	105	115	120	130	140	150	160
4	120	130	135	145	160	170	180	190
5	140	150	160	170	185	195	210	225
6	160	170	180	195	210	225	240	255
7	180	190	205	220	235	255	270	290
8	200	210	225	245	265	280	300	320
9	220	235	250	265	290	310	330	350
10	240	255	270	290	315	340	360	385

Table 4 Pivot point on edge of traveled way — curve in direction opposite to normal pavement slope

W_L=width of ramp lane.

Superelevation Transitions for Ramp Curves

Figure 642-6b